



Using the Delphi Method to Study the Criteria Affecting the Decision Regarding the Investment in Conveyor Systems

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Abstract

An increase in the number of companies registered in Thailand between 2004 and 2009 has led many companies to be more aware of their own potential for increased sales. A major concern for every company is the material handling design because it is a major capital expenditure. When considering the material handling system design, the conveyor system selection is one of the important key factors and its cost is normally 30-70 percent of the total material handling cost. Conveyor system selection consists of various-criteria, or factors, that have to be considered at the same time. The purpose of this article is to study both the criteria and sub-criteria based on the Delphi method that have an impact to the executive's decisions on the conveyor system. The Delphi method is a reliable tool that allows consensus to be formed among groups of panelists. A group of 18 panelists was selected and questionnaire was designed, as an open-ended questionnaire in the first round and the results of previous round are built to be the second and final round based on the Delphi method to identify the appropriate criteria and sub-criteria for the conveyor system selection. This study, which consisted of four main criteria: benefit, opportunity, cost and risk. These main criteria have a strong influence on the decision making involved in the conveyor selection. Finally, this study concludes that further research is needed to explore the relationship between the criteria and the case study.

Keywords: The Delphi method, Conveyor system

1. Introduction

Anywhere, there must have material handling around people's daily life, but seems it is not interesting thing especially in trade and industry. In fact, modern life, it is extremely rare not to be used for materials handling such as lifting, moving, storage and other activity

The study on metal processing industries have discontinuous process, it was found only five percent of the total production time is work on the machine the other ninety-

five percent is waiting and movement [1] and each industry, the cost of material handling will be approximately 30 – 70 percent or more of the total cost of production but it depends on the type of industry [2]. The initial cost of manufacturing operation can reduce 15 – 30 percent by manage efficient material handling [3], [4], [5], [6]. Thailand is developing country which is one country have industry growth (Fig. 1) and continuous economic growth because Thailand has appropriate factor support, such as labor, natural resources and other factors. In every business, there are material handling's activities and including a small and medium enterprise (SME) or even in daily life. Today, there is not only high domestic competition among businesses, but also high international competition. As the World Economic Forum (WEF) ranking that is about ranking of competitive capability all over the world. It presented that Thai is ranked in 38th from the total of 139 countries [7]. A competitive advantage that Thai can compete with other countries is cheaper price or higher quality of product than others. From previous information that 30-70% of product value involved with material handling, if businesses can improve the efficiency of material handling to be better, then these businesses can save the 15-30% of total costs [3], [4], [5], [6]. To increase the efficiency of production, businesses should be put right quality of material to the right place at the right time [8], [9]. Therefore, it seems that the decision of suitable material handling system selection is so importance as a way to increase profits and reduce costs [4]. Each industry has different material handling activity, whether loading or unloading depending on type of industry. Most of the currently, the decision to invest in material handling equipment relies on leader or executive of each company. But "material handling equipment selection problem is an important decision making area for the companies, since it has a direct effect on manufacturing and service productivity".

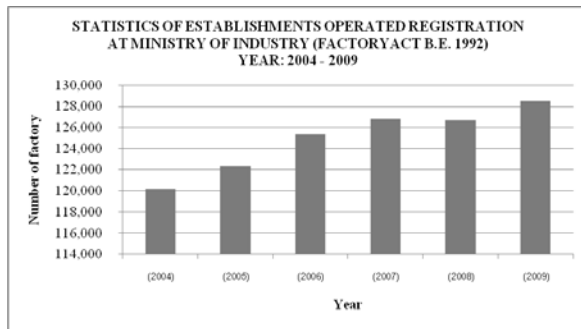


Fig. 1. Statistics of establishments operated registration at ministry of industry (factory B.E. 1992) Year: 2004 – 2009.

For the investment analysis in choosing the material handling system, it is extremely complex and there are more solutions for particular situation [10]. The material handling selection problem, it is importance [11] and there are many factors or criteria concerned and necessary to consider. The factors may be material handling equipments, manufacturing type, working area, product appearances, environment, functional equipments, Material handling method and other factors [12]. The criteria are also affected by significantly constrains or other criteria such as the product size, the characteristics of the product that it is handled, space and time required etc [13]. Thus, the Delphi method was utilized to solve the appropriate both criteria and sub-criteria selection problems. The Delphi method is a reliable tool that can reach the consensus among group through the iterative processes and non-bias outcomes.

2. Background theory

2.1 Material handling system

Material handling is defined by American Society of Mechanical Engineer as the art and science involving the moving, packaging and storing of substances in a form. Although the best solution to the materials handling problem, is no handling, or the simplest solution to the materials handling, no movement no cost. Both solutions are hardly possible for a complete manufacturing process. Therefore, the main objective of material handling is to decrease the number of handling equipments [14].

A material handling system (MHS) is system for improve performance of a manufacturing system such as reducing work-in-process (WIP) delivering the right amount of materials, to right place, at the right time and at the lowest cost [4].

2.1.1 Material handling equipment

In manufacturing system, Material handling equipment (MHE) is the most important part and it is playing an important role in the productivity of the manufacturing as increasingly rate. The selection of MHE system is complex and there are considerable of capital investment required. As the handling activities account for 30-40% of the production costs [15], so the appropriate MHE should be selected by aiming to reduce production cost and increase profit.

Material handling equipments are divided into seven main group of conveyor, overhead conveyors, cranes, industrial trucks, automated guided vehicles (AGVs) robots and storage/retrieval systems.

2.1.2 Conveyor system

A complexity of conveyor equipment selection is a problem for many manufacturers [16]. There are several factors and limitation involving with conveyor equipment selection. A conveyor system is a part of mechanical handling equipment that used to move materials from one location to another [17]. Wherever several of the materials to be handled and the move to be performed, so a various types of conveyor can be used. The types of conveyors can be categorized in several ways. For example, a belt conveyor can be used for bulk and unit loads, so it can be located overhead or on the floor as Table 1 [18]. Bulk materials that are grain, dry chemicals and saw dust, these can be conveyed using a chute, belt, bucket or vibrating conveyors. Unit materials that are castings, machined parts, and materials placed on pallets and cartons or tote boxes, these can be conveyed using chute, belt, roller, wheel, or tow conveyors. Material can be conveyed on belt, roller, wheel, vibrating, pneumatic or tow conveyors.

2.1.2.1 Type of conveyors

Fonseca and team [16] have been developed a prototype computer-based system for selecting the suitable conveyor equipment from a list of 76 conveyor types such as belt conveyors, chain conveyors, monorail system, bucket conveyors, pneumatic conveyors, roller conveyors, gravity conveyors, screw conveyors, vertical conveyors, vibrating conveyors and other conveyors. These conveyor types have categorized into 2 main types of unit and bulk handling conveyor according to the material types that they handled.

1) Unit handling conveyors: Unit handling can benefit in many working areas such as automotive assembly lines, order picking in warehouses, can conveying in food plants, and stacking materials in storage racks with lift trucks [19].



2) Bulk handling conveyors: The characteristics of bulk material handling can be presented by continuous-flow, involving materials in an aggregate form, often in unpackaged form. The materials that it handled can be solids, fluids and gas. For example, grains, grits, dry powder, dry powders, granules, flakes, resins, coal, fertilizer, sulfur, and salt [20].

Table 1 Conveyors analysis.

Conveyors							
	Belt	Bucket	Chain	Monorail	Pneumatic	Roller	Screw
Material							
Type							
-Individual Item	X	X		X	X	X	
-Packaged	X		X	X		X	
-Unit				X	X	X	
-Bulk	X	X			X		X
Quantity-Total							
-High	X	X	X		X	X	X
-Medium	X	X	X	X	X	X	X
-Low				X			
Move							
Load Handled							
-Uniform	X	X	X	X	X	X	X
-Variable	X	X	X	X	X	X	X
-Unit Load				X			
Rate/Speed							
-Uniform	X	X	X	X	X		X
-Variable	X	X	X	X		X	X
Frequency							
-Regular	X	X	X		X	X	X
-Irregular				X	X		
-Continuous	X	X	X		X		X
-Intermittent	X	X	X	X	X	X	X

2.2 Delphi method

"Delphi" is name of the ancient Greek temple where people could be found the oracle [21]. The Delphi method as a research tool was developed by Norman Dalkey of the RAND Corporation, the Santa Monica, California in the 1950s. The purpose of this technique is to get reliable consensus in the opinion of a panel of selected expert [22]. It is widely popular in many fields, such as education, business, education, health care, engineering and other fields [22], [23].

The Delphi method is a repetitive process to collect knowledge and consensus from multiple experts by using series of questionnaires. This technique is a way to reduce the negative face-to-face interactive and panelist have equal opportunity for sharing idea or feel, such as "the tendency of low-status members in spite of contrary feeling" [24], [25] subordinate in panelist have different feeling or idea. Major

characteristics of the Delphi method are that the list of members or respondents were not disclosed, respondents must be familiar or expert in the topic of research not general person, questionnaires have repeating process three or four rounds, have feedback reports (qualitative feedback) between researcher with the panel and have quantitative feedback such as medians, inter-quartile ranges, and standard deviation to group member or panelists [23].

3. Methodology

In this study, the main criteria are based on reviewing relevant literature. Sub-criteria of the proposed will be screened and confirmed by group of experts. A panel of experts is comprises of people who related in 3 main groups that are: faculty of teachers in department of engineering, executive or engineers who are user in conveyor system and executive or engineers who produce and service in business of conveyor system. Those supporters are utilized to screen and confirm sub criteria through Delphi method. In Fig. 2 shows steps of Delphi method that the explanation is follow:

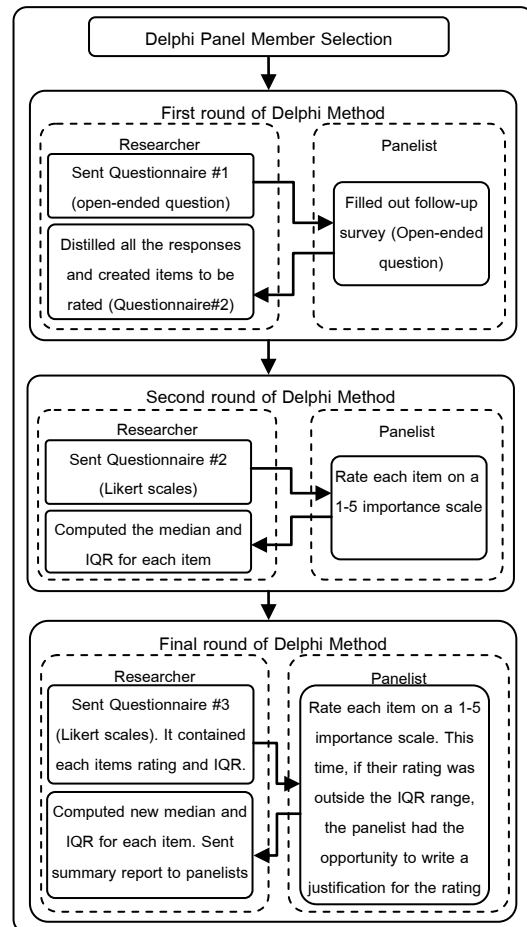


Fig. 2. Steps for Delphi method.



3.1 Panelist selection

A group of panelists in this research consists of people 3 groups who are experts of conveyor system or related in business of conveyor system.

- Industrial engineering and material handling engineering academic.
- Executives or engineers who are user in conveyor system.
- Executives or engineers who are produce and service in business of conveyor system.

3.2 Questionnaires formation

Each round of questionnaire is based on the Delphi method. The first is open-ended questions and the number of experts in this round is 17 person. For this round, there are 4 main criteria that consist of benefit, opportunity, cost and risk.

Benefit (positive) means the benefits gained that should be considered in selecting the conveyor system and it can be separated into two parts:

- Technical
- Benefit from used

Opportunity (positive) means the opportunities occurred of buyer and user that should be considered in selecting the conveyor system.

Cost (Negative) means the costs that should be considered before selecting, during implementing and after running of the conveyor system.

Risk (Negative) means the risks or uncertainties occurred that should be considered in selecting the conveyor system.

In the second round, questionnaire of this round is different from the first round because it was built as close-ended question. For Criteria in this questionnaire, those are generate by summary the answers from the previous round. An respondents will be considered criterion each based on Likert scales as following:

- Level of agreement
- 1 = Strongly Disagree
 - 2 = Disagree
 - 3 = Neither agree nor disagree
 - 4 = Agree
 - 5 = Strongly agree

Questionnaire in this round, it consists of 4 sections as same as the previous round. Final round, questionnaire is the same as the previous round, except adding the median, interquartile range and previous answer of respondents for each item. All respondents can change or reconfirm their own

answer in this round.

3.3 Statistics and data analysis

Data analysis is based on Delphi method. The data analysis for second and third round, it will be analyzed base on median and interquartile range through using Microsoft Excel 2007. Meaning of median of Delphi method as follow Table 2 [26].

Table 2 Meaning of median range.

Median	Meaning
< 1.50	The dimension is strongly disagreed among experts.
1.50 - 2.49	The dimension is somewhat disagree among experts.
2.50 – 3.49	The dimension is neither agreed nor disagreed among experts.
3.50 – 4.49	The dimension is somewhat agreed among experts.
≥ 4.50	The dimension is strongly agreed among experts.

For Interquartile Range (IQR), it can calculate by finding the different between the 1st quartile (25th percentile) and 3rd quartile (75th percentile). The meaning of interquartile range (IQR) is showed in Table 3 [26].

Table 3 Meaning of interquartile range.

Interquartile range	Meaning
≤ 1.50	The result is consensus among experts to criterion is received
> 1.50	The result is consensus among experts to dimension is not received

4. Result

The major goal of the study is to determine the main criteria that used for decision making in conveyor system investment. Final important criteria are derived from the screening through the Delphi method. Those are 42 sub-criteria and divided into four main criteria categorized that are Benefit (B), Opportunity (O), Cost (C) and Risk (R). All factors are listed in the Table 4.

In Table 4, each criterion is determined by the answer of 18 experts. The factors that was considering criteria as median is greater than or equal to 4.5 and interquartile range (IQR) is less than or equal to 1.5. The mode comparison between academic group and all experts, it explored that



there are more consensus as majority (Fig. 3).

Table 4 Result from Delphi method.

Benefit (Technical)	<ul style="list-style-type: none"> • Description of product, • System & Functionality, • Priority process of order, • Speed & Process capacity, • Compatibility, • Variety of product , • Space, • Ease of usage and setup, • Ease of improvement, • Safety, • Maintenance, • Ease of purchase spare part, • Cost of energy consumption (energy saving)
Benefit (Used)	<ul style="list-style-type: none"> • Save cost, • Stability, • Reduce mistake & defect, • Space utilization, • Quality system, • Reducing activities or repetitive activities • Reduce unit cost, • Reduce process human activity, • Image, • Distance of transport
Opportunity	<ul style="list-style-type: none"> • Increase productivity, • Increase efficiency, • Reduce defect, • Reduce number of human resource • Customer satisfaction, • Reduce mistake, • On time delivery
Cost	<ul style="list-style-type: none"> • Initial investment, • Software cost, • Upgrade & improvement cost, • Hidden cost, • After sale service, • Maintenance cost, • Labor cost & Operation cost
Risk	<ul style="list-style-type: none"> • Global economy, • Financial risk, • New process or new description of product • Own readiness, • Maintenance

For example, the sub-criteria in which the rating where level of agreement was strongly agree and the IQR was less than 0.5 were description of product, system and functionality,

speed and process capacity, stability, quality system, increase productivity, increase efficiency and maintenance.

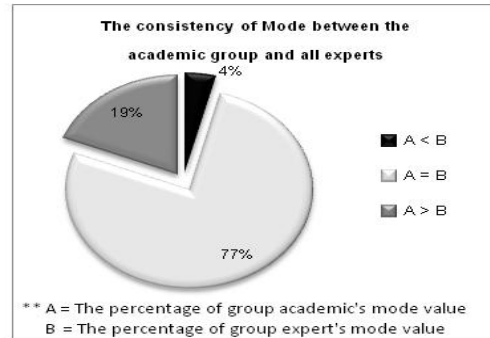


Fig. 3. The consistency of Mode between the academic group and all experts.

5. Conclusion

The present expansions of various industrial, a small and medium enterprise have highly competitive. They cannot refuse one activity that is material handling's activities. Therefore, it is important to manage or improve the quality of material handling to be better, so the applying the Delphi method can detect and analyze the factors which are important for supporting in decision making of a conveyor system investment. These factors were considered through screening by experts and series of questionnaires. This research can solve the multi decision making problems involved with various criteria for the conveyor system investment. Form results, this study found that initial investment, maintenance, efficiency and labor cost, and operation cost have high agreement among experts. The experts involved with the conveyor systems confirmed that these sub-criteria were essential factors for acquiring the appropriate conveyor systems, in addition to the previous study of Tuzkaya, Chan, and Braglia [6], [11], [28] that they mentioned about these sub-criteria also. The identified criteria provide a conveyor system selection model for next future research.

Acknowledgements

The authors acknowledge the contribution of the 18 participants (Industrial engineering and material handling engineering academics, executives or engineers who are user in conveyor system, Executives or engineers who are produce and service in business of conveyor system) who participated in this study.



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